MIG WELDING OF DISSIMILAR METAL USING DIFFERENT THICKNESSES (ALUMINUM AND MILD STEEL)

MUHAMAD FADHLI BIN ZAINUDDIN

Thesis submitted in fulfilment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering with Manufacturing Engineering

BACHELOR OF ENGINEERING
UNIVERSITI MALAYSIA PAHANG

JUNE 2012

ABSTRACT

In this project, the main objective is to study the optimum thickness ratio of the different material combination joint and also weld joint's quality on the various gauge ratios and the defect. Tailor welded blanks (TWBs) of combinations different material and with various of thickness were weld by using Metal Inert Gas (MIG) welding before do the test. Thus aluminum AA1100 with thickness 1, 2, 3, and 4 mm and mild steel with thickness 2, 3, and 4 mm were studies and combination to form TWBs of different thickness ratios of 0.33 (1/3 mm), 0.5 (1/2 mm), 0.66 (2/3 mm), 0.25 (1/4 mm), 0.5 (2/4 mm) and 1.5 (3/2 mm). The joint were evaluated by mechanical testing and metallurgical analysis. Microstructural analyses were done by using metallurgical microscopic and also Vickers hardness testing and tensile testing were used to investigate optimum gauge ratio. The fracture in tensile tests occurred at the interfacial layer of the aluminum-mild steel joint layer zone. Result of this analysis find that 0.33 gauge ratio is optimum gauge ratio with maximum force 1670 N. the factor that effect of maximum force joint is intermetallic layer. in microstructural analysis the hardness for mild steel will increase at heat affected zone (HAZ), while hardness of aluminum will decreases at HAZ. During the experiment, some of defects were found at specimen such as spatter, incomplete fill and porosity but the best specimen only used for experiment.

ABSTRAK

Objektif utama projek ini ialah untuk mengkaji nisbah ketebalan yang optima apabila menggabungkan dua bahan yang berbeza. Serta kecacatan kesan dari pencamtuman dua bahan berbeza ini. Kaedah yang di gunakan untuk mencantum dua bahan yang berbeza ini ialah kimpalan logam gas lengai. Oleh itu, aluminium AA1100 dengan ketebalan 1, 2, 3, dan 4 mm dan keluli lembut dengan ketebalan 2, 3, dan 4 mm digunakan untuk mengkaji kombinasi dua jenis bahan ini dengan pelbagai nisbah ketebalan. Nisbah ketebalan untuk projek ini ialah 0.33 (1/3 mm), 0.5 (1 / 2 mm), 0.66 (2/3 mm), 0.25 (1/4 mm), 0.5 (2/4 mm) dan 1.5 (3/2 mm). Gabungan ini diuji dengan menggunakan ujian mekanikal dan logam analisis. Hasil analisis ini mendapati bahawa 0.33 adalah nisbah yang paling optima dengan daya tarikan maksima 1670 N. Faktor yang memberi kesan daya maksimum adalah lapisan intermetalik. Dalam analisis mikrostruktur, kekerasan pada keluli lembut akan meningkat pada kawasan yang terjejas dengan haba ketika proses kimpalan, manakala kekerasan aluminium akan berkurangan pada kawasan yang terjejas dengan haba. Semasa eksperimen dijalankan, beberapa kecacatan telah dijumpai pada bahagian sambungan seperti yang berselerak, isi tidak lengkap dan keliangan tetapi spesimen terbaik hanya digunakan untuk eksperimen.

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURES

LIST OF SYMBOLS

HV	Vickers Hardness Number
L	length
N	Newton
P	Load
s	Second
V	Voltage

LIST OF ABBREVIATIONS

AA	Aluminum Alloy
Al	Aluminum
ASTM	American Society For Testing And Material
CO_2	Carbon Dioxide
FZ	Fusion Zone
GMAW	Gas–Metal Arc Welding
GTAW	Gas–Tungsten Arc Welding
HAZ	Heat Affected Zone
MIG	Metal Inert Gas
PMZ	Partially Melted Zone
SEM	Scanning Electron Microscope
SMAW	Shielded Metal Arc Welding
TEM	Transmission Electron Microscopy
TWBs	Tailor Welded Blanks

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Welding is a process in which materials of the same fundamental type or class are brought together and caused to join (and become one) through the formation of primary (and, occasionally, secondary) chemical bonds under the combined action of heat and pressure (Messler, 1993). The definition given in 'The American Heritage Dictionary' states: "To join (metals) by applying heat, sometimes with pressure and sometimes with an intermediate or filler metal having a high melting point". The definition found in IS0 standard R 857 (1958) states, "Welding is an operation in which continuity is obtained between parts for assembly, by various means," while the motto on the coat of arms of The Welding Institute (commonly known as TWI) simply states "e duobusunum," which means "from two they become one." All the definition is slightly different but the process is to combine or joint two or more material with heat, pressure or by adding another metal.

When significant melting is involved and necessary for welding to take place, the processes are called fusion welding processes (Messler, 2004). That has 3 type of fusion welding which is gas welding, arc welding and high - energy beam welding. Arc welding that can be grouped into several categories such as Shielded metal arc welding (SMAW), Gas–tungsten arc welding (GTAW), and Gas–metal arc welding (GMAW). This project uses GMAW or is also referred to as metal-inert gas (MIG) welding process. MIG is a process that melts and joins metals by heating them with an arc established between a continuously fed filler wire electrode and the metals. The main advantage of MIG is that the mode of molten metal transfer from the consumable wire electrode can be intentionally changed and control led through a combination of shielding gas composition, power source type, electrode type and form, arc current and voltage, and wire feed rate. Besides that the advantage of MIG is a much higher deposition rate, which allows thicker work pieces to be welded at higher welding speeds compare to the GTAW process (Chair, 2003).

A tailor welded blanks (TWB) is composed of more than two materials with similar or different strengths or thicknesses joined together to form a single part before the forming operation (Kinsey et al., 2001). The main advantage of using a TWB is that it gives thicker or stronger materials at critical parts of the sheet metal blank so as to increase the local stiffness. This can also reduce the weight of automotive panels, .TWB offer an excellent opportunity to reduce manufacturing costs, decrease vehicle weight, and improve the quality of sheet metal stampings (Kinsey et al., 2001). TWB are used in such places as door inner panels, lift gates, and floor pans.

Tailor welded blanks with different thickness, quality and also with different protective coatings such as galvanized, nickel-plate and chrome-plate) are the most frequently welded using various techniques welding. Dissimilar metal joining offers the potential to utilize the advantages of different materials often providing a whole structure with unique mechanical property. Aluminum can reduce the weight of structural parts for its light weight and steel has a high strength and excellent corrosion resistance (Shi et al., 2010). Therefore, it has become a hot research field in recent years to joining aluminum alloy and steel together.

1.2 PROBLEM STATEMENT

The variety of material has its own characteristics, types of properties and different structural component. Material may fail due to a variety of reasons. From a previous research that has done by other researches, there are a lot of TWB studies by using many type of welding. However the research only uses one parameter of TWB (i.e. thickness only or different material only). Therefore, the information about MIG welding of dissimilar metal and using different thickness ratio is scarce. Because of that, this project focuses to combine the parameter to find optimum thickness (gauge ratio) for TWB joint. Currently, there have a lot joining that must be combined using more than one parameter. And because of increasing interest for a wide range of transportation industries on TWB, a detailed research on the quality welding and optimum thickness ratio of aluminum-steel dissimilar welding is of huge importance.

1.3 PROJECT OBJECTIVES

The objectives of the project are:

i. To investigate the weld joint's quality on the various gauge ratio and defects of steel and aluminum joint.
ii. To investigate the optimum thickness ratio of the steel and aluminum joints=.

1.4 PROJECT SCOPE OF WORK

The scope of this study includes:

i. Fabrication of steel and aluminum weld using various thickness ratios.
ii. Study of weld quality and defect by using mechanical test device using tensile test and Vickers Hardness test.
iii. Study of microstructure of joint by using Optical Microscope.

CHAPTER 2

LITERATURE REVIEW

2.1 WELDING

Welding is the most common method of joining two or more pieces of metal to make them as a single piece. Welding can use to join all commercial metals and alloys and also to join different type and strength of metal. It is often said that more than 50% of country gross national product is related to welding in one way or another because welding the most economical and efficient way to join metals permanently (Kinsey et al., 2001). Welding begins as a repair or maintenance tool and now has become as a most important manufacturing method as well as the most essential construction method. In manufacturing almost all metal is welded because of its strength and versatility. Welding is use in the manufacture of almost all the products that we use in daily lives such as to construct the vehicles that transport us and the product we use. Today's, automotive would be much more expensive if not use welding as the method to construction. The steel body and frame of car use spot-welded by robot, arc welding and also laser beam welding.

There are many different welding processes and type of welds. One of the most popular welding processes is arc welding. Figure 2.1 show a welding process behind the hood using arc welding.

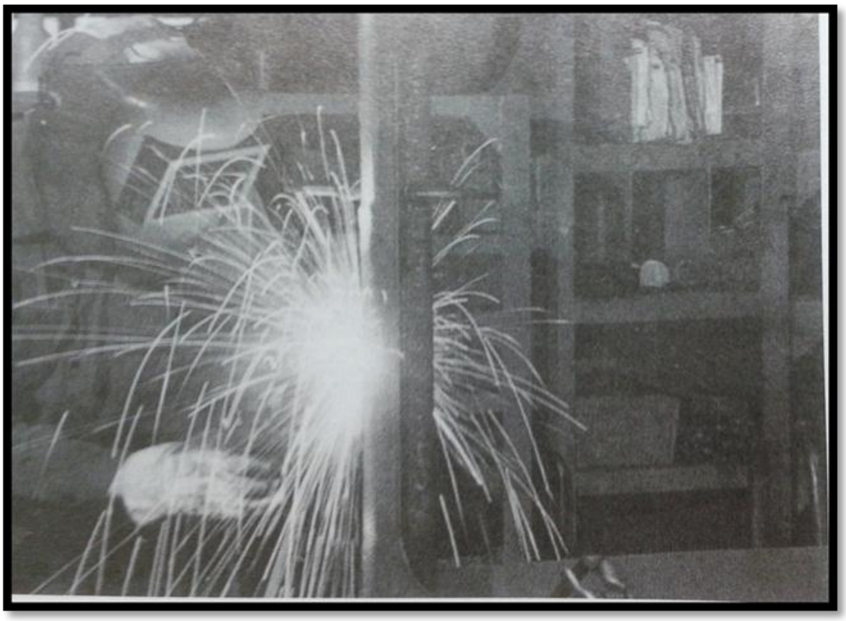

Figure 2.1: Welding process using arc welding

Source: Cary and Helzer, 2005

2.1.1 Welding Group

The American Welding Society (AWS) has made each welding process definition as complete as possible. The society defines a process as a grouping of basic operational elements used in welding. The group of welding is arc welding oxyfuel gas welding, resistance welding and solid state welding. Coalescence is defined as the growing together or growth into one body of the materials being welded, and applicable to all group welding. Figure 2.2 show the welding process that is divided into four groups.

By using a welding that has a lot of advantages. Some of these advantages use welding are:

i. It is lowest cost, permanent joining method.

ii. It affords lighter weight through better use of materials.

iii. It joints all commercial metals.

iv. It can be used anywhere.

v. It provides design flexibility

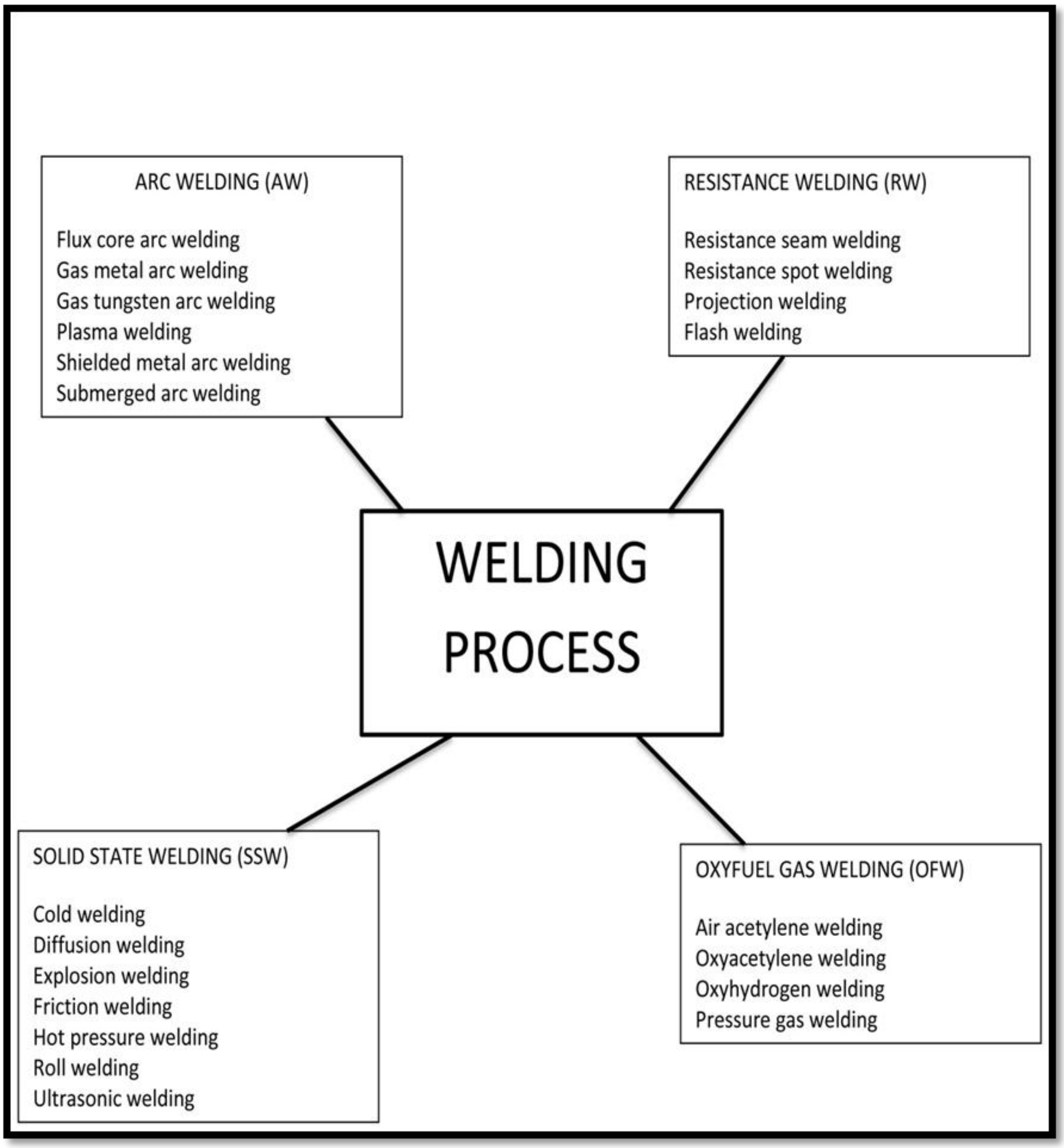

Figure 2.2: AWS master chart of welding process

Source: Cary and Helzer, 2005

Arc welding is a group of welding processes that produce coalescences of workpieces by heating them with arc. Oxyfuel gas welding is a group of welding processes that produces coalescences of workpieces by heating them with an oxyfuel gas flame. Resistance welding is a group of welding processes that produces coalescences of the faying surface with the heat obtained from resistance of the workpieces to the flow of the welding current in a circuit of which the workpieces are a part, and by the application of pressure. Solid-state welding is a group of welding processes that produces coalescences by the application of pressure without melting any of the joint components (Cary and Helzer, 2005). So in these projects that involve TWB technology, the process that use is metal-inert gas (MIG) welding.

2.1.2 Gas Metal Arc Welding

Gas metal arc welding (GMAW) is an arc welding process that uses an arc between a continuous filler metal electrode and the weld pool. The process is used with shielding from a supplied gas and without the pressure. GMAW has developed in late 1940s for welding aluminum and has become popular. This process is also called metal inert gas (MIG) welding that is shown in figure 2.3.

Figure 2.3: MIG welding process.

Source: Cary and Helzer, 2005

MIG welding process uses the heat of an arc between a continuously fed consumable electrode and the work to be welded as in a figure 2.4. The heat of the arc melts the surface of the base metal and the end of the electrode. The metal melted off the electrode is transferred across the arc to the molten pool and the molten weld metal must be properly controlled to provide a high-quality weld. The depth penetration is controlled by many factors, but the most important factor is the welding current. If the depth of penetration is too great, the arc welding will burn through thinners material and affect the quality of welding. The width of molten pool based on many factor also but the most important factor is travel speed.

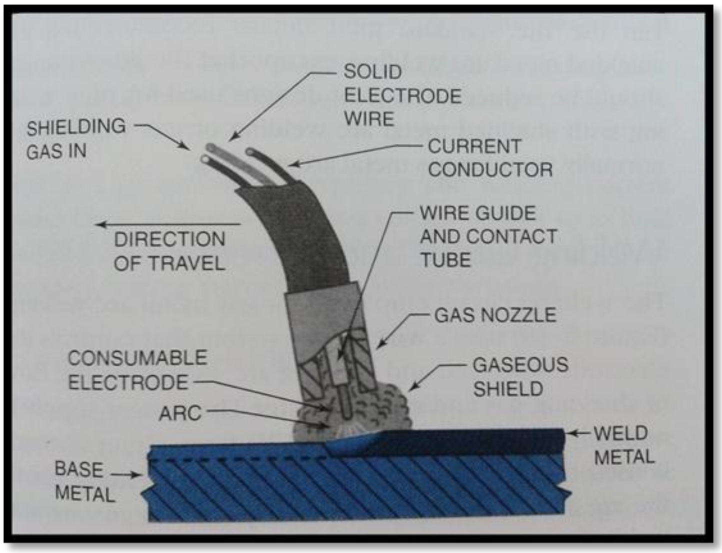

Figure 2.4: Process diagram for MIG welding.

Source: Cary and Helzer, 2005

An envelope of gas fed through the nozzle provides shielding of the molten pool, the arc and the surrounding areas show in figure 2.4. This shielding gas, which may be an inert gas, an active gas, or a mixture, surrounds the area to protect it from contamination from atmosphere. The electrode is fed into the arc automatically, usually from a coil of wire. The arc is maintained automatically and travel guidance can be handled manually or by machine. The metal being welded dictates the composition of the electrode and the shielding gas (Cary and Helzer, 2005).

Irrespective of the particular source of heating in MIG welding, fusion welds exhibit distinct microstructural regions as a direct result of the various effects of the heat. Figure 2.5 shows a schematic of a typical MIG weld that will create high and low temperature heat-affected zone (HAZ), Fusion zone (FZ) and partially melted zone (PMZ) (Hicks et al., 2007).

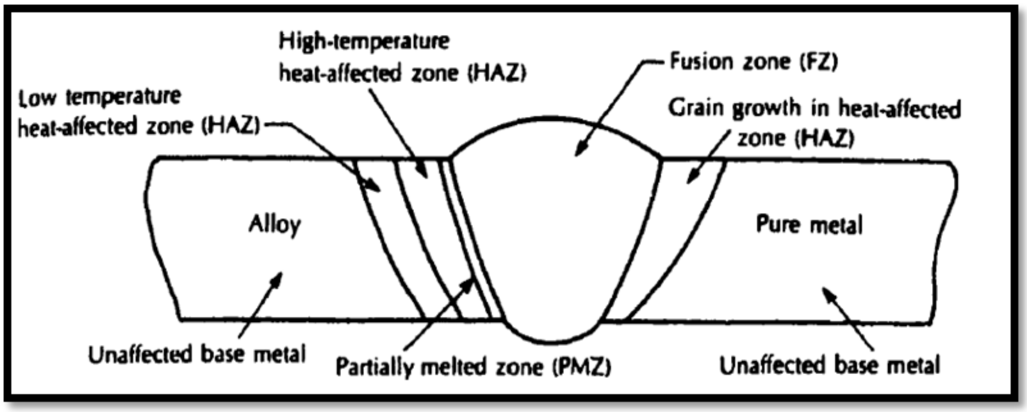

Figure 2.5: A schematic of a typical MIG weld that will create high

Source: Chair, 2003

In MIG welding there has lot of advantages but the major advantages of MIG welding are:

i. High operator factor
ii. High deposition rates
iii. High use of filler metal
iv. Elimination of slag and flux removal
v. Reduction in smoke and fumes
vi. Lower skill level in a semiautomatic method of application than that required for manual shielded metal arc welding.
vii. Automation possible
viii. Versatility, with wide and broad application ability

2.1.3 Gas Metal Arc Welding Equipment

The equipment for MIG system as in the figure 2.6 consist of power source, the electrode wire feeder, the welding gun, the gas and water control system for the shielding gas and cooling water when used.

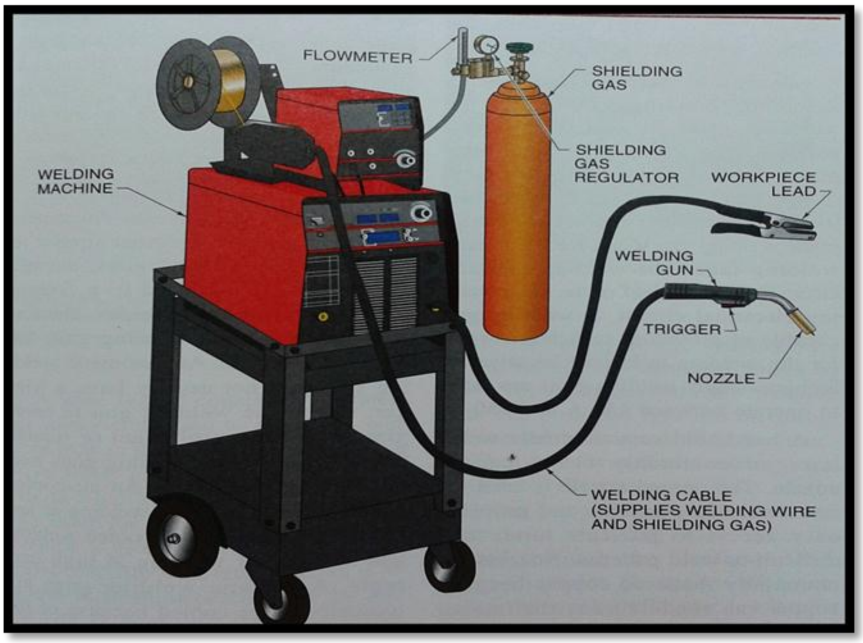

Figure 2.6: MIG welding system with equipment

Source: Jeffus, 2009

The power source can be a rectifier, an inverter, or, for field use, a generator welding machine. For the short circuiting arc variation 200-A machine is normally used. The voltage remains relatively constant as set on the machine, while the amperage increases or decreases according to the distance of the nozzle and wire from the work. The Amperage in MIG welding is controlled by the wire speed setting on the wire feed unit. The welding machine is usually set to provide DC reverse polarity current (Jeffus, 2009).

The electrode wire feeder unit may be placed on the machine, located close to the machine or built in to the machine depending on manufactures style and type of machine. Although styles is different but have the same basic function. The electrode wire feed unit supplies a constant and smooth rate of filler wire from a spool mounted on the back of the unit (Jeffus, 2009). A gas cylinder with attached regulators is hooked up to the wire feed units solenoid to supply the gas shielding. The filler wire and gas are fed to the arc by the attached gun.

The welding gun or welding torch is attached to the wire feed unit to deliver the filler wire, the welding gas and shielding gas to the welding arc . The welding lead cable is constructed to allow electrical flow, conduct the shielding gas and feed the filler wire through the gun to the arc. In addition to the electrical wiring, the welding lead has a gas hose running through it to carry the gas supply and a liner to conduct the wire typical MIG gun has a handle with a trigger and nozzle (Jeffus, 2009). The gun has a power connector that plugs into either the machine or the wire feed unit. In the case of the units with a separate wire feeder, the gun also has a wire feed connection.

2.1.4 Shielding Gas

The selection of the correct shielding gas for a given application is critical to the quality of the finished weld. The criteria used to make the selection include, but is not restricted to, the following: Alloy of wire electrode.

i. Desired mechanical properties of the deposited weld metal.
ii. Material thickness and joint design.
iii. Material condition – the presence of millscale, corrosion, resistant coatings, or oil.
iv. The mode of GMAW metal transfer.
v. The welding position.
vi. Fit-up conditions.
vii. Desired final weld bead appearance.

The thermal conductivity, or the ability of the gas to transfer thermal energy, is the most important consideration for selecting a shielding gas. High thermal conductivity levels result in more conduction of the thermal energy into the workpiece. The thermal conductivity also affects the shape of the arc and the temperature distribution within the region. Argon has a lower thermal conductivity rate — about 10% of the level for both helium and hydrogen. The high thermal conductivity of helium will provide a broader penetration pattern and will reduce the depth of penetration. Gas mixtures with high percentages of argon will result in a penetration into the base material, and this is due to the lower thermal conductivity of argon (Jeffus, 2009).

Carbon dioxide (CO2) is the most common of the reactive gases used in MIG welding and the only one that can be used in its pure form without the addition of an inert gas. Compared to helium its thermal conductivity is low. Its energy required to give up an electron, ionization energy, is low, and this results in the finger-like penetration profile associated with its use. Carbon Dioxide supports axial spray transfer. Nickel, copper, aluminum, titanium, and magnesium alloyed base materials use carbon dioxide shielding (Jeffus, 2009). In this project gas carbon dioxide will use as a shielding gases.

2.1.5 Electrode Classification

The American welding society (AWS) has a standard method to identify MIG electrode. This standard uses series of letter and numbers to group filler metal into specifies classification. The AWS specification is for the chemical and physical properties of the weld produced by the filler metal and not specific composition of wire (Cary and Helzer, 2005). This allows manufacturers to make slight changes in the electrode composition as long as the weld is produced with the electrode meets the group specifications.

Most of manufacturers of filler metal have trade names unique to their products. A composition charts is available from each manufacturers that list it product names as they relate to the AWS-numbers electrodes. These chart are helpful when it is necessary to make sure that a particular wire meets a code or standard or when changing from to supplier to another. The mild steel filler is use for this project which is its same to the one of parent material.

2.2 TAILOR WELDED BLANKS

The use of tailor welded blanks (TWB) has increased in practice and is being introduced in all the fields of use of metal materials. When introducing the technology of TWB, it is important to select the material and thickness of the semi-product correctly, but it also extremely important to select a proper welding process to joining TWB. The focus on TWB in this project is to joint two different materials with the different gauge ratio. Only an optimum choice of material and material pairs for welded joints, proper design of semi-products, welded joints and welded edges, selection of the joining procedure and technology and correct measures before to, during and after welding can ensure the manufacturing of high quality products (Tusek, 2001). Figure

2.7 shows a schematic of current and potential TWB application in automotive industries that use in frame rail, floor pan, rear door inner, windshield frame and others part.

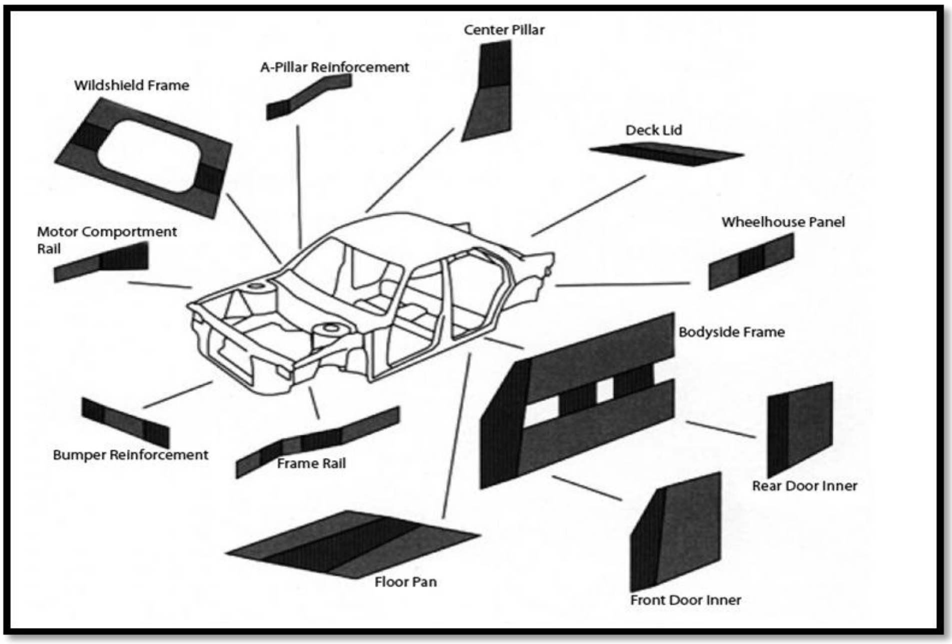

Figure 2.7: A schematic of a TWB application in automotive industries

Source: Kinsey et al., 2001

2.2.1 Previous Research

Most researches on TWB have concentrated in quantifying only one parameter either different thickness joining or different material only but not both parameters. But in many real-life engineering manufacturing it involves both parameters. Chan et al. (2003) has studies on TWB that focus on different thickness material by using SPCC steel sheets. Venkat et al. (1997) investigated Aluminum alloys 5754-O and 6111-T4 which have the combination of different material only. Zhang and Liu have conducted the experiment by using aluminum alloy 2B50 and stainless steel 1Cr18Ni9Ti as the material but joint with the same thickness.